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IMP A

USE: EXPLORER 18 SATELLITE

NASA TO LAUNCH INTERPLANETARY EXPLORER SATELLITE

The first launch of the Interplanetary Explorer (IMP A) satellite will be conducted no earlier than November 12 by the National Aeronautics and Space Administration from the Atlantic Missile Range, Cape Canaveral, Fla. This is the first of a series of seven planned IMP (Interplanetary Monitoring Platform) satellites.

Essentially a compact, satellite-borne physics laboratory, IMP's mission is to measure magnetic fields, cosmic rays and solar winds in interplanetary space--the region beyond the influence of the Earth's magnetic field.

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The orbit planned for IMP A is a highly eccentric one. At apogee it will fly almost three-quarters of the distance to the Moon. It will spend more than two-thirds of each orbit outside the Earth's magnetic field in interplanetary space.

The first IMP will carry nine scientific experiments. These were contributed by scientists from the Universities of California and Chicago, the Massachusetts Institute of Technology, the NASA Goddard Space Flight Center, and the NASA Ames Research Center.

One of the key objectives of the IMP series is to study charged particle radiation emanating from the Sun and sources beyond the Sun in interplanetary space over a period of relatively quiet solar activity through the more active phases, thus covering a significant portion of the 11-year solar cycle.

Information on radiation levels in interplanetary space gathered over extended periods and at many levels is of importance to NASA's Apollo manned lunar landing program. Some data on this hazard to manned flight beyond the Earth has been obtained by earlier satellites--particularly the Explorer series--and by balloon and sounding rocket flights. This information has shown that during periods of intense disturbances on the Sun, showers of solar cosmic rays (high energy protons) raise the radiation levels in interplanetary space. (Protons are the exceedingly small, charged portions of the nucleus of all atoms.)

Information on interplanetary radiation levels can be used in the design of protective shielding for manned spacecraft, and ultimately to develop a prediction capability for these solar events thus permitting scheduling of flights during anticipated periods of solar inactivity.

The way-out orbit of IMP A is also expected to give scientists added information on the composition and depth of the back of the magnetosphere--the envelope formed by the Earth's magnetic field which protects man from the radiation levels experienced in interplanetary space. The magnetosphere is tear-drop shaped and extends behind the Earth away from the Sun to as yet undefined limits. It is hoped that IMP will map this region which is believed to trail off behind the Earth like the tail of a comet.

Overall, the Interplanetary Explorer series will make scientific observations in the same general area of interplanetary space over an extended period of the solar cycle. These long-term observations may result in clearer understanding of the development and dynamics of the solar system.

General Information

The Interplanetary Explorer satellite is part of the scientific space exploration program of NASA's Office of Space Science and Applications. It is managed by the Goddard Space Flight Center,

Greenbelt, Md. The satellite was designed, built, and tested as an in-house project of Goddard.

IMP A's weight of 138 pounds consists of 35 pounds of scientific instruments. Its basic design is similar to the earlier highly successful Explorer XII, XIV and XV satellites, also managed and built by Goddard. It is essentially a continuation of the NASA series of "energetic particle" spacecraft on which some of its experiments have already been successfully flown. It has an octagon-shaped base, 12 inches deep and about 28 inches in diameter. All but two of its experiments are mounted in this eight-sided base.

IMP A's distinguishing physical feature is the manner in which its magnetometers have been mounted to avoid interference from the weak magnetic field generated by the satellite itself. Protruding from the top of the satellite--like a one-sided dumbbell--is a rubidium-vapor magnetometer mounted on a boom which telescopes out to a distance of six feet after orbit is achieved. Two flux-gate magnetometer sensors--folded at time of launch--extend on booms each seven feet away from the satellite.

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IMP is spin stabilized and powered by solar cell arrays mounted on four paddles which charge its thirteen silver cadmium batteries. Its tiny four-watt transmitter weighs one and one-half pounds and will be capable of transmitting to the NASA world-wide network of tracking and receiving stations at distances over 173,000 miles.

The launch vehicle for IMP A is the reliable three-stage Delta produced for NASA by the Douglas Aircraft Company. Delta will be trying for its 20th consecutive successful satellite launching in 21 attempts. The IMP A Delta will fly for the first time a higher thrust third stage motor, the X-258, which generates 5,700 pounds of thrust.

In some respects this will be one of Delta's most crucial tests. If IMP A is to achieve its extreme cigar-shaped orbit, it must be accelerated almost to the velocity required for an Earth-escape mission--some 24,000 miles an hour. If it has too much speed at the point of injection into orbit, it will fly beyond the Earth's gravitational field and "escape" into orbit around the Sun--out of range of the ground stations.

Another "cliff-hanging" aspect of the IMP A launch is that it will take at least a week to confirm that the satellite has indeed achieved its planned orbit. The nominal orbital period is 153 hours--more than six days.

The satellite will be launched at an angle of inclination to the equator of 33 degrees. At its high point or apogee the satellite will go out more than 173,000 miles. Its perigee or orbital low point is about 125 miles above the Earth.

The launch can be made only during a one and one-half hour period each day and the launch time is calculated to take full advantage of the gravitational influences of the Moon and the Sun. These influences, coupled with those of the Earth, may eventually increase the satellite's perigee to about 20,000 miles and thus prolong its useful lifetime.

Assuming that the planned orbital objectives are attained, IMP A could operate as long as 12 months. However, many of its basic scientific objectives will be fulfilled if an operating lifetime of three months is achieved.

The Scientific Objectives

Interplanetary Magnetic Fields. For thousands of years man has looked into the seeming infinity of space and thought of it as an empty void. Only recently has this thesis been proved incorrect.

We now know that far from being an empty expanse, space is filled with an ionized gas--an electrically neutral mixture of atomic ions and electrons.

The distance between the atoms that make up particles in space is great--many times greater, for example, than the air around us. Unlike air in the atmosphere, particles in space move at tremendous speeds. Their continual movement throughout the universe is controlled by magnetic fields.

A variety of magnetic fields are believed to exist in the universe. The exploration of space has opened the door to an understanding of the origins of these fields and how they control the movement of particles in space.

In our solar system, however, it is the Sun's magnetic field that conditions the movement of particles in interplanetary space. These fields are dramatically altered by periodic disturbances which occur on the surface of the Sun. These are called solar flare events--some of which shower deadly protons along with other energetic particles into the solar system toward the Earth. The movement of these energetic particles is controlled for the most part by the magnetic field lines in which they travel.

Near the Earth still another magnetic field--of terrestrial origin--turns away these showers of radiation or it deflects them into the vicinity of the magnetic poles. This deflection starts at the boundary of the Earth's magnetic field called the magnetopause.

The IMP with its unique geocentric orbit of high eccentricity permits the investigation of major magnetic field phenomena in space. The primary interest in the study of the interplanetary medium is the interplanetary magnetic field and its ambient state. In addition the associated interactions of the streaming solar plasma and the geomagnetic field are prime subjects for investigation within the IMP orbit. Simultaneous measurements of magnetic field phenomena on the IMP spacecraft and later spacecraft will provide additional information about interplanetary space.

The basic device for measuring the magnetic fields is called the magnetometer. For its mission, IMP A will carry two different types of magnetometers.

- A rubidium-vapor magnetometer--a three-pound ball-shaped device 13 inches in diameter, mounted six feet above the satellite's main base. (Goddard Space Flight Center)
- Two fluxgate magnetometers, each mounted on seven-foot booms in the base of the satellite. (Goddard Space Flight Center)

The magnetic field experiments will measure the magnitude and direction of the magnetic field in space with high accuracy and precision. This data will be particularly significant regarding the development of theories on the present physical state of the interplanetary medium, its dynamical characteristics and the interactions of the streaming solar plasma with the geomagnetic field.

The primary purpose of the experiments is to measure the interplanetary magnetic field undisturbed by the presence of the Earth's field. In addition the instrumentation is appropriate for measurement of fields in the vicinity of the geomagnetic cavity boundary and the interaction region associated with the solar streaming plasma and the geomagnetic field.

The rubidium vapor magnetometer, which measures magnitude of magnetic fields is employed with a bias coil system which permits directional measurements. Included also are two fluxgate magnetometers which precisely measure the direction of weak magnetic fields. The instrumentation is complimentary in that the rubidium vapor magnetometer permits the calibration of the zero levels of the fluxgate magnetometers in flight.

The dynamic range of the fluxgate sensors is $\pm$ 40 gammas (1 gamma = 10^{-5} gauss) with an accuracy of $\pm$ .16 gammas. The dynamic range of the rubidium vapor magnetometer is 0.1 gammas to 1000 gammas. The magnetic field strength near the Earth varies from 30,000 gammas at the equator to about 70,000 gammas at the poles.

Cosmic Rays. Cosmic rays--which are not rays at all but high energy particles--consist of protons, alpha particles and heavier nuclei. There are two sources of cosmic rays: those which originate from outside the solar system and are of very high energy and those which come from the Sun during certain periods of solar flare activity.

Galactic Cosmic Rays. These high energy particles come from outside the solar system. What causes them is not clearly understood. One theory suggests that since the Sun produces particles with energies of up to several billion electron volts during some eruptions and it is likely that at least some of the particles ejected escape the solar system, then, by the same token other stars, like the Sun or larger, produce particles of equal and greater energies.

Cosmic radiation from galactic sources is present at all times in the solar system. The interplanetary magnetic field is not strong enough to deflect them. Only during periods of intense solar flare activity does their frequency, at least in the vicinity of the Earth, decrease. This phenomenom is called the Forbush decrease and is observed when an intense solar flare event occurs on the Sun.

It is theorized that the magnetic field lines of the tongue of energy reaching out from the Sun to envelop the Earth during these periods are strong enough to deflect galactic cosmic rays. It has been noted that during periods of comparative solar quiet--such as the one the Sun is presently entering--the frequency of galactic cosmic radiation tends to increase.

It is also known that the intensity of cosmic radiation varies with the Earth's latitude and is more intense at the poles. Since cosmic ray particles have tremendous energies, they penetrate deeply into the Earth's atmosphere. When these fast-moving particles collide with particles in the atmosphere they produce many kinds of lower-energy radiation.

<u>Solar Cosmic Rays</u>. Solar cosmic rays are similar, although they have less energy than those of galactic origin.

The surface of the Sun is in continual turmoil because of the perpetual production of energy from its interior. With a frequency that varies with the solar cycle--but at, as yet, unpredictable times--the Sun's surface becomes especially turbulent and it ejects clouds of charged particles into space. The high energy charged particles they spew out are known as solar cosmic rays.

When a flare occurs at the proper place on the Sun, clouds of highly charged particles spew out into space and reach the Earth. Some of the particles--especially protons--interact with the Earth's atmosphere. When this occurs--often with great suddenness--magnetic storms, radio blackouts, auroral displays and other phenomena, still little understood, take place.

Both types of cosmic radiation--galactic and solar--will be studied by instruments on board IMP A. Four experiments will measure their intensity, composition and direction.

- A device first flown on Mariner which employs solid-state detectors and a range-energy loss telescope to search out charged particles of comparative low energy. This device will study the particle spectrum and its nuclear composition, concentrating on hydrogen, helium and lithium. Since we are entering a period of comparative solar quiet, now is an opportune time to detect these low energy particles which are believed to be of galactic origin. The device will also monitor in detail the particle energies resulting from solar flares which may occur during the satellite's lifetime. It is also designed to look for low energy trapped protons in the Earth's magnetosphere. (University of Chicago)

- Two pancake-shaped geiger counters--called particle telescopes--will be employed to obtain data on the direction and flux of cosmic rays produced by a large solar flare. Knowing the direction and flux, it is hoped that an integrated idea of interplanetary magnetic fields can be obtained. (Goddard Space Flight Center)

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- A particle telescope which will measure the flux of galactic cosmic rays and identify hydrogen, deuterium, tritium and helium in energy ranges of from 12 to 80 million electron volts. The flux of electrons of energy from one to 20 million electron volts will also be studied. If successful, this data will provide scientists with the first measurement of energetic electrons in space beyond the Van Allen belt. If electrons exist in the interplanetary region, time variations in observed fluxes could provide direct evidence about their origin. (Goddard Space Flight Center)

- An ion chamber to measure the presence of proton radiation and determine its quantity in terms of a dose rate of reontgens per hour. Changes in intensity of cosmic radiation caused by flare activity also will be recorded.

An exploratory experiment consisting of two geiger counter tubes so situated that they will detect electron fluxes in various energy regions. The type of electron energy being sought by these detectors is known to exist in the radiation belts of the Earth and plays an important role in many geophysical phenomena. If this electron energy flux is found to exist in interplanetary

space it may be possible to determine what role the Sun plays in supplying energy to the Earth's radiation belts. (University of California)

Solar Winds. In addition to the high energy solar cosmic rays which bombard the solar system with deadly radiation following a solar flare event, the Sun continuously gives off a steady stream of very low energy charged particles. This flow of energy is called the solar wind or solar plasma. It travels at a velocity of up to 300 miles-per-second and has a density of about 10 particles per cubic centimeter at the orbit of the Earth.

One school of thought is that solar wind is merely an extension of the Sun's atmosphere or corona. We do know that during periods of solar activity--flares--the velocity of the solar wind increases.

One of the most dramatic effects of the solar wind is that it apparently distorts the shape of the geomagnetic 'cavity in which the Earth is located. This cavity or envelope is called the magnetosphere.

The Sun side of the magnetosphere, it is believed, tends to be compressed toward the Earth because of the pressure exerted

upon it by the continual flow of solar wind. The portion of the magnetosphere which extends behind the Earth away from the Sun is believed to trail off at some as yet unknown limit. Thus, from a perspective in space, the solar wind tends to shape the magnetosphere in an "air foil" or aerodynamic manner. The mapping of the backside of the magnetosphere, and determining its composition, is one of the major scientific objectives of the IMP program.

Three experiments will study the effects of solar wind in interplanetary space.

- A curved-plate electrostatic analyzer will separate solar particles in terms of their energy. After separation, the particles will produce a current--which is a function of the energy level--and can be measured by an electrometer circuit. The device is calibrated to determine solar wind particle flux in the vicinity of the IMP A. To do its job, proton concentrations are determined by admitting them through a slit of known dimensions in the side of the satellite. (NASA Ames Research Center)

- Another way of measuring the solar wind is to use a device which permits particles to enter a six-inch-diameter surface through a series of grids which separates electrons and low-energy positive particles. This instrument can determine the flux, speed, and direction of motion of the particles analyzed. (Massachusetts Institute of Technology)

- A small sensor called the thermal ion electron experiment will collect particles and measure the amount of electrical charge they carry. Portions of solar wind to be measured include positive and negative ions and electrons. It is hoped that the data obtained will provide an indication as to whether these low energy particles constitute a gas which is stationary or whether this gas moves as part of the solar wind . (Goddard Space Flight Center)

The Orbit of IMP

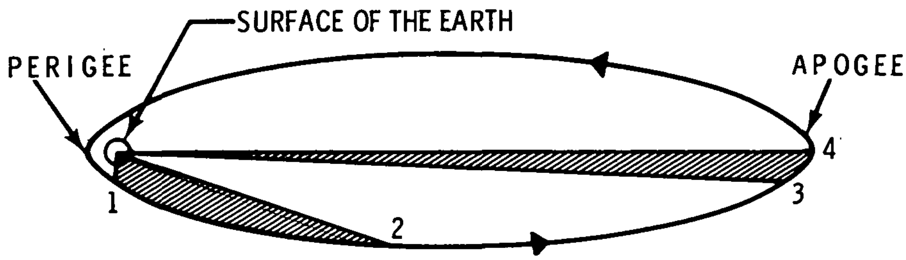
The cigar-shaped orbit of IMP A is one of the most unusual ever attempted for an Earth-orbiting satellite. This orbit is known as a "highly eccentric ellipse."

To accomplish its interplanetary monitoring mission, IMP A will spend two-thirds of its time in interplanetary space outside the Earth's magnetosphere. Some of the physical laws governing such an eccentric orbit deserve to be outlined.

IMP A will begin its orbit at a perigee of about 125 miles above the Earth. It will move out into space until it reaches a high point of about 173,000 miles. In terms of speed, the orbit will have almost a roller coaster effect. As it approaches perigee it will whip around the Earth and back out into space at a speed

of 23,400 miles an hour. Traveling outward on its elliptical path the force of the Earth's gravitational field will gradually exert its force until, at apogee, it has slowed to a speed of slightly more than 350 miles an hour. Thus, IMP A will appear to hang stationary in space at apogee.

This change of speed can be explained by Kepler's law of areas. Basically, a straight line connecting the satellite with the center of the Earth passes over equal areas in equal times. Thus, it takes a satellite the same time to travel along the arc of its orbit between points 1 and 2, as illustrated below, as it does to travel between points 3 and 4 at apogee.



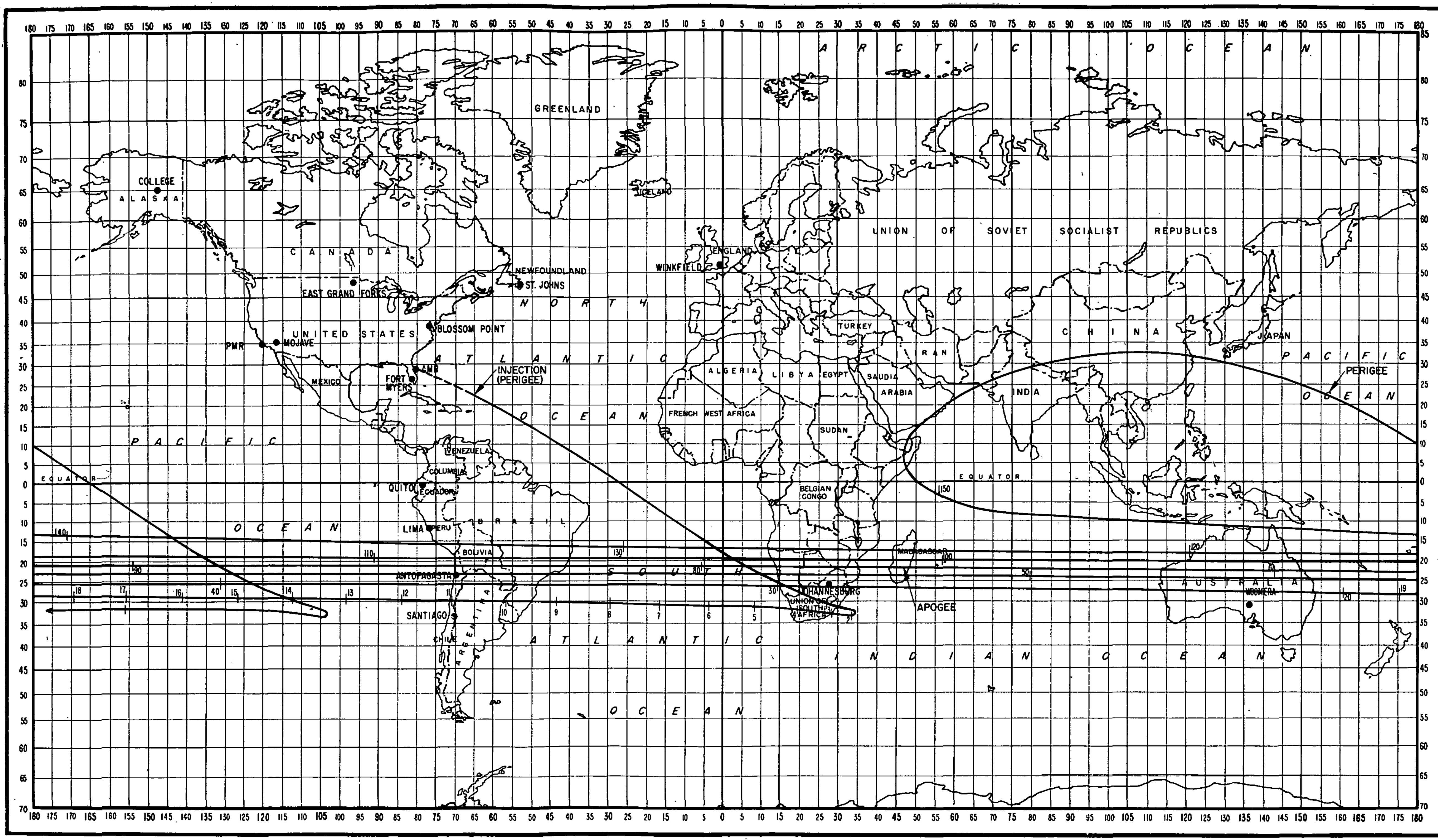
IMP ORBIT
(Approximately to scale)

If the gravitational field of the Earth was the only force governing the satellite's orbit, it would fly through space in a perfect unvarying ellipse--except for small pertabations caused

by the flattening of the Earth. However, the gravitational fields of the Moon and the Sun will tend to distort the ellipse. This means that the eccentricity of the orbit will gradually change. By computing these effects, and then launching at the proper time, the eccentricity can be decreased and the orbit intentially made rounder. Thus, the perigee of IMP A will initially move farther away from the Earth, and the useful lifetime of IMP A will be increased significantly.

The gravitational forces of the Moon and the Sun will have other effects on the orbital motion of the satellite around the Earth. During its first orbit, for example, IMP A will not pass over the Earth higher than 33 degrees latitude. However, as these forces come into play, the so-called "tilt" of the orbit with respect to the Earth's equator will gradually increase until after a year it will overfly high northern latitudes of the Earth.

Thus, the highly elliptical orbit will provide an unusual opportunity to study the motion of the satellite as a number of gravitational fields act upon it. Since, in relation to the orbits of planets, IMP's orbital period is small and its variations large, it is possible to observe these effects in terms of months. It would take centuries to observe similar changes of planetary motions.



S-74 INTERPLANETARY MONITORING PLATFORM-NOMINAL SUB-SATELLITE PLOT

Note: Tic marks indicate time in hours after injection.

APOGEE	172,000 Miles
PERIGEE	125 Miles
PERIOD	150 Hours
INCLINATION	33 Degrees

The IMP Team

The National Aeronautics and Space Administration's Office of Space Science and Applications is responsible for the Interplanetary Explorer Satellite. The IMP A satellite was designed, built and underwent environmental testing at the Goddard Space Flight Center, Greenbelt, Md., which is responsible for management of the Interplanetary Explorer project.

The prime contractor for the Delta launch rocket is the Douglas Aircraft Company, Santa Monica, Calif. Douglas is also responsible for pre-launch and launch operations under the supervision of the Goddard Field Projects Branch at Cape Canaveral.

The Air Force Missile Test Center which operates the Atlantic Missile Range will provide logistic support for the IMP A launch.

Key officials responsible for the Interplanetary Explorer program and its experiments are:

NASA Headquarters

Dr. Homer E. Newell, Associate Administrator for Space Science and Applications

Dr. John E. Naugle, Director, Geophysics and Astronomy Program Division

Dr. John Freeman, Program Scientist

Eugene Ehrlich, Program Engineer

T. Bland Norris, Delta Program Manager

Goddard Space Flight Center

Dr. Harry J. Goett, Director

Paul Butler, Project Manager

Gerald W. Longanecker. Assistant Project Manager

Dr. Frank B. McDonald, Project Scientist

William R. Schindler, Delta Project Manager

The Experimenters

Magnetic Field Experiment--	Rubidium vapor magnetometer Dr. Norman F. Ness, Goddard Space Flight Center
Magnetic Field Experiment--	Fluxgate magnetometer Dr. Norman F. Ness, Goddard Space Flight Center
Cosmic Ray Experiment--	Range versus energy loss Dr. J. A. Simpson, Enrico Fermi Institute, University of Chicago
Cosmic Ray Experiment--	Energy versus energy loss Dr. Frank B. McDonald and Dr. George Ludwig, Goddard Space Flight Center
Cosmic Ray Experiment--	Ion chamber and Geiger counter tubes Dr. Kinsey A. Anderson, University of California
Solar Wind Experiment--	Low energy proton analyzer Dr. John Wolfe, Ames Research Center

Solar Wind Experiment--	Plasma probe Dr. Herbert S. Bridge, Massachusetts Institute of Technology
Solar Wind Experiment--	Thermal ion electron sensor Robert Bourdeau and Gideon P. Serbu, Goddard Space Flight Center

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Fact Sheet: The IMP Satellite

Weight:	138 pounds
Main structure:	Octagon, 28 inches by 28 inches; 12 inches deep
Appendages:	Four solar paddles, 26 inches long by 18 inches wide
	Four antennas, 16 inches long
	Rubidium-vapor magnetometer, on six-foot boom
	Two Fluxgate magnetometers on seven-foot booms

Power system

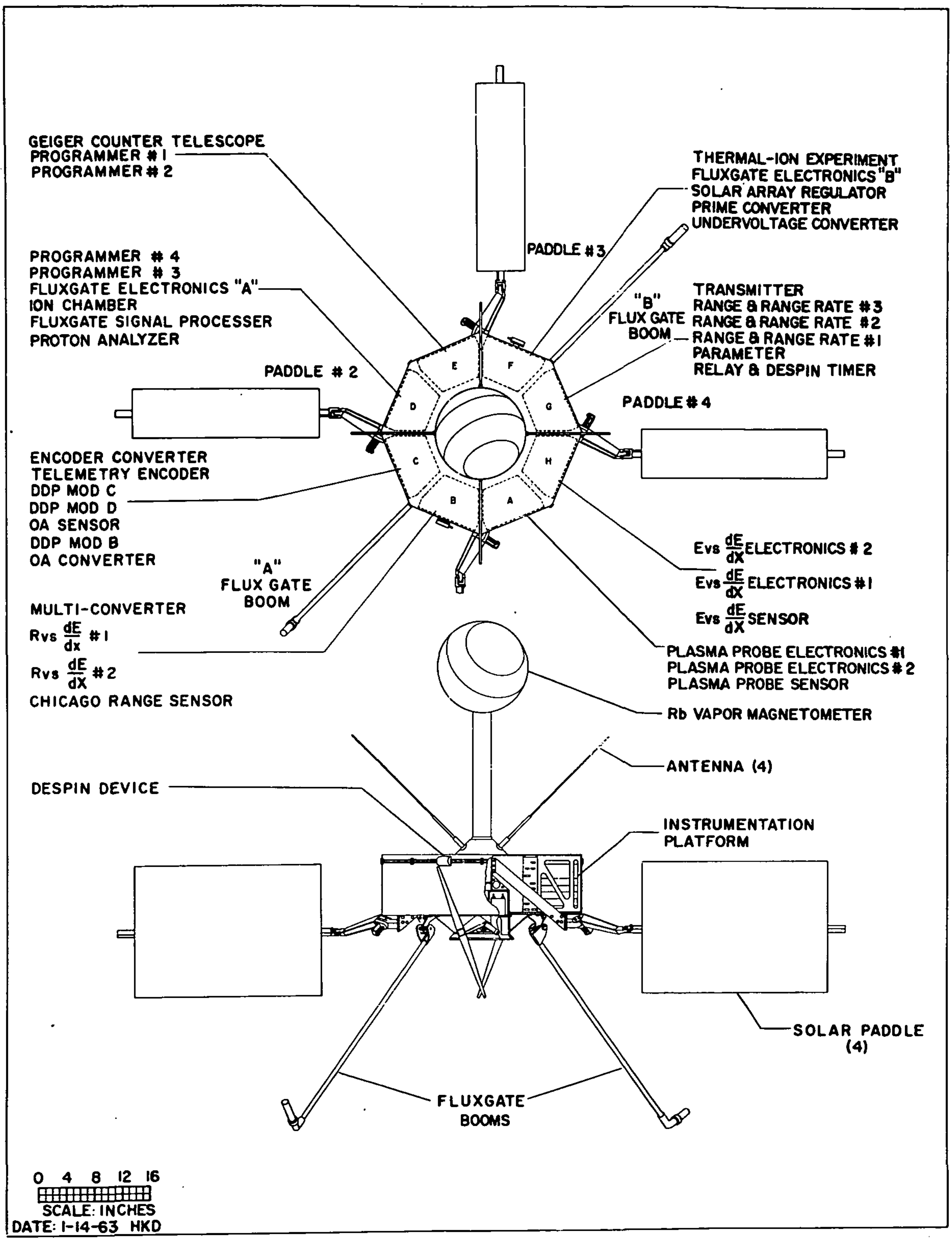
Power supply:	Solar cells, mounted on four solar-oriented arrays; one 14-volt five-ampere-hour battery pack
Voltage:	12 to 19.6 vdc
Power:	38 watts

Communications and data-handling system

Telemetry:	Pulsed-frequency modulation (PFM)
Transmitter:	4-watt output
Encoder:	PFM with digital data processor (DDP) for accumulation and storage of data

Tracking

Tracking stations:	Apogee - Johannesburg, South Africa Rosman, North Carolina Carnarvon area of Australia



IMP

GODDARD SPACE FLIGHT CENTER
GREENBELT, MD.

	Perigee - Blossom Point, Maryland Fort Myers, Florida Goldstone, California
<u>Data-Acquisition stations</u>	Johannesburg, South Africa Woomera, Australia Santiago, Chile
<u>Range and Range Rate stations</u>	Scottsdale, Arizona (Motorola) Rosman, North Carolina

The Delta Launch Vehicle

The NASA-developed, three-stage Delta rocket will be used to launch IMP A into orbit. If successful, this will be the 20th consecutive satellite launched into orbit by Delta. To date, the Delta record includes 19 successes and one failure.

The IMP Delta will fly a higher-thrust third stage motor for the first time. This will give it the higher thrust needed to place IMP A in its highly eccentric orbit. The Delta program is managed by the Goddard Space Flight Center.

The Delta rocket has the following general characteristics:

Height: 90 feet

Maximum Diameter: 8 feet

Lift-off Weight: About 57 tons

First Stage: Modified Air Force Thor, produced by Douglas Aircraft Co.

Fuel: Liquid (Kerosene with liquid oxygen as oxidizer)

Thrust: 170,000 pounds

Burning Time: About two minutes and 25 seconds

Delta Space Weight: Over 50 tons

Second Stage: Aerojet General Corporation, JA 10-118 propulsion system

Fuel: Liquid

Thrust: About 7,500 pounds

Burning Time: About one minute, 40 seconds

Delta Space Weight: Two and one-half tons

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<u>Third Stage</u>: Allegany Ballistics Laboratory X-258 motor

Fuel: Solid

Thrust: About 5,700 pounds (vs 3,000 pounds for X-248)

Burning Time: 26 seconds (vs 40 seconds for X-248)

Weight: About 576 pounds (vs 516 pounds for X-248)

Length: 59 inches (vs 57.5 inches for X-248)

Diameter: 18 inches (same as X-248)

During first and second stage powered flight, the Bell Telephone Laboratory radio-guidance system is used for in-flight trajectory corrections. It also commands second-stage cutoff when the desired position, velocity and altitude have been achieved.

Following second stage cutoff, a 27-second coast period occurs. During this period, small rockets mounted on a table between the second and third stages ignite and spin up the third stage and the satellite to their proper velocity. The second stage then separates and third stage ignition occurs, giving IMP A its final boost toward orbital injection. Once in orbit, IMP A's spin rate will be approximately 20 rpm.

The chief Douglas Delta system engineer is J. Kline and G. R. Hansen is head of the Douglas Field Office at Cape Canaveral.

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